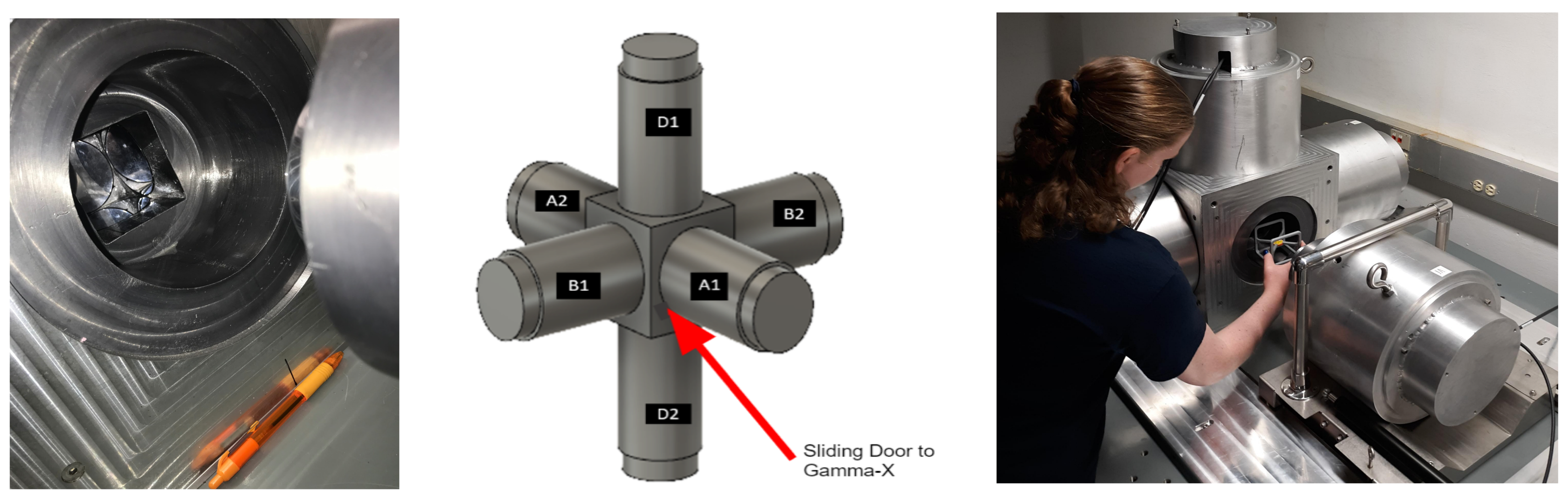
Radioactive Decay Calibrations of RICS using 41 Ar

Emily Vanderbilt, Sarah Mandanas, Nicole Gindling, Gabriel Stash, Dr. Stephen Padalino - State University of New York at Geneseo
Salvatore Ferri, Tyler Kowalewski, Steven Raymond, Dr. Mark Yuly – Houghton College

Acknowledgements
Laboratory for Laser Energetics

Abstract

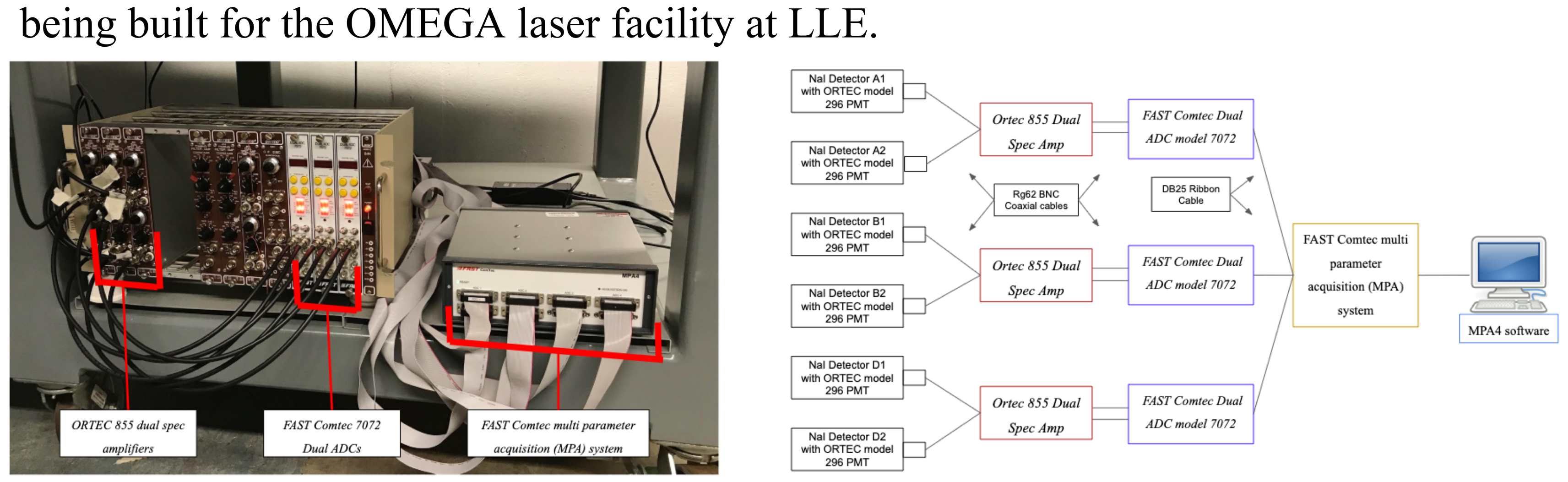
The rapid isotope-counting system (RICS) being built for the OMEGA laser facility at LLE requires relatively short-lived gaseous radioisotopes for calibration purposes. 40Ar was bombarded with thermal neutrons to produce 41Ar via the 40Ar(n,gamma) reaction using the SUNY Geneseo neutron howitzer, which contains a Plutonium-Beryllium (Pu-Be) source. To increase the likelihood of neutron capture, liquid 40Ar (Lar41) was used a target in the Howitzer. Once activated, the Lar41 undergoes beta decay 99.1% of the time producing an electron with an endpoint energy of 1.198 MeV. The daughter product, 41K, is formed in the second excited state. It promptly decays to the ground state of 41K emitting a 1.293 MeV gamma ray. To accurately measure the activity of 41Ar as a calibration source for RICS, the Gamma-X counting system has been repurposed as a low background gamma-ray counting station.



(Center) The Gamma-X detector arrangement. (Left) A view into the inside chamber of Gamma-X with the detectors in place. (Right) Gamma-X with the door open allowing for placement of source inside the lead shielding.

Motivation

If the radioactive isotope of argon can be successfully created using the Pu-Be source, then Gamma-X could be used to calibrate the rapid isotope-counting system (RICS) being built for the OMEGA laser facility at LLE.



(Above) MPA4 software and additional NIMBIN Units. The Ortec 855 Dual Spec Amps, FAST Comtec 7072 Dual ADC, MPA bus box, and connecting wires.

Experimental Setup

Gamma-X is composed of 3 orthogonal pairs of Thallium doped NaI detectors which surround a central cubic counting region having a volume of approximately 1 liter. Each of the six detectors is shielded in 11.5 cm of lead and clad in aluminum to reduce background radiation. The multi coincident capabilities of the six detectors have been tested and the NaI detectors calibrated.

(Left) Ar styrofoam dewar cube. (Right) Ar styrofoam dewar cup. Both styrofoam dewars were created to hold liquid 41Ar for analysis in the Gamma-X chamber. The styrofoam was wrapped in reflective aluminized tape to reduce the evaporation rate of liquid Argon. The argon evaporation rate was measured to be ~1.5 mg per second.

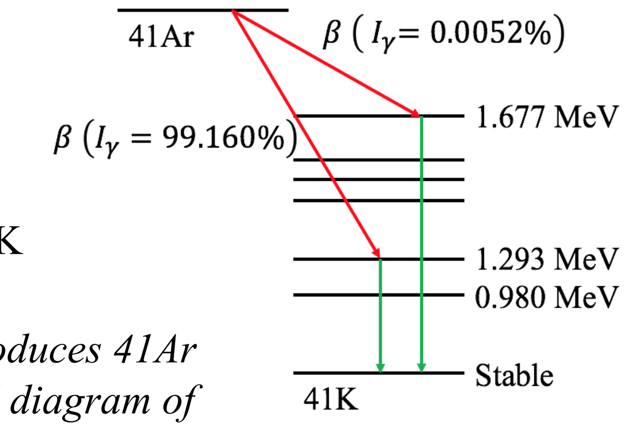
Procedure

Liquid 40Ar was transferred to the Pu-Be source. Neutron capture occurs and the 41Ar is transferred into the Gamma-X counting set up. The six NaI(Th) detectors were used to detect the gamma ray emitted by the decay product, 41K and create growth curves.

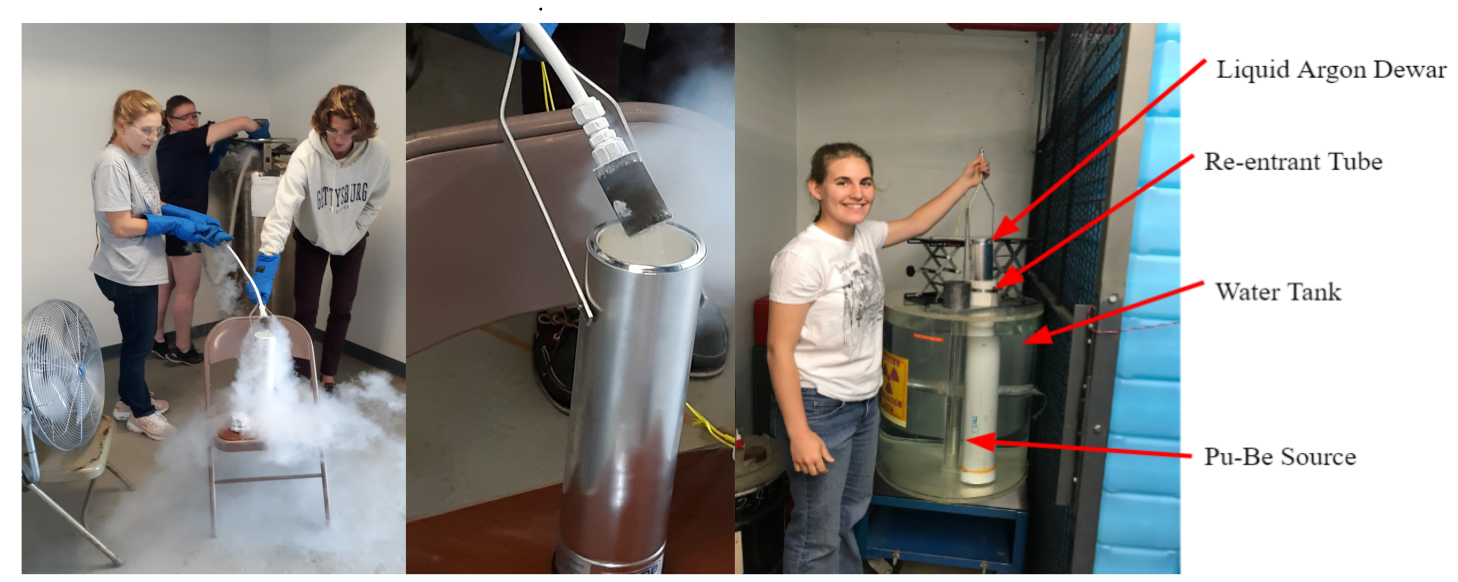
40Ar(n,γ)41Ar

41Ar→ e + 41K*

41K* → γ+41K



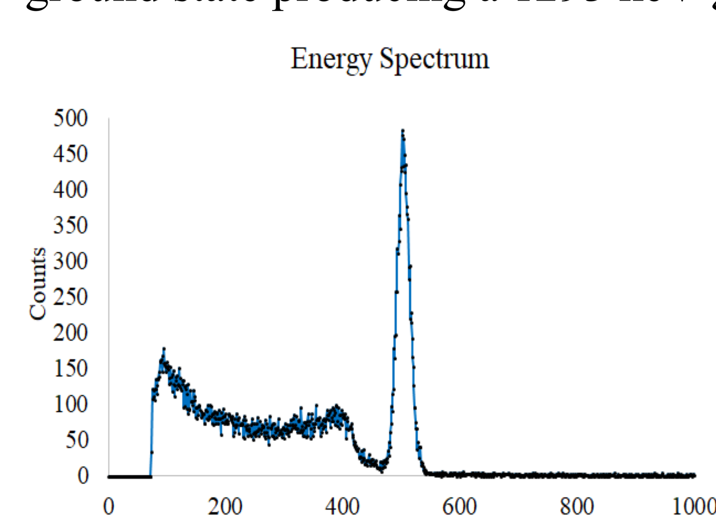
(Above) The neutron transfer reaction that produces 41Ar and its subsequent gamma ray. (Right) A level diagram of 41Ar's beta decay and gamma radiation.

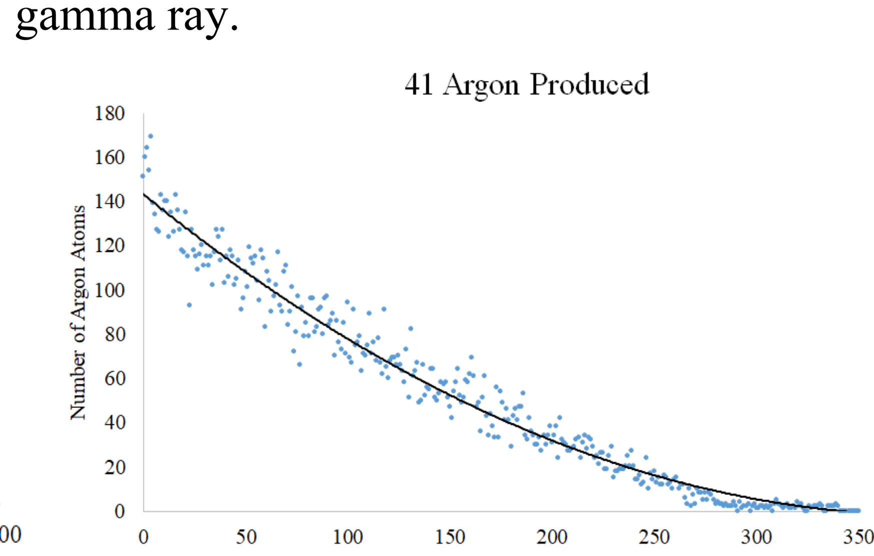


(Left) Research students at SUNY Geneseo placing liquid 40Ar into a 300 ml. dewar for transportation and irradiation.

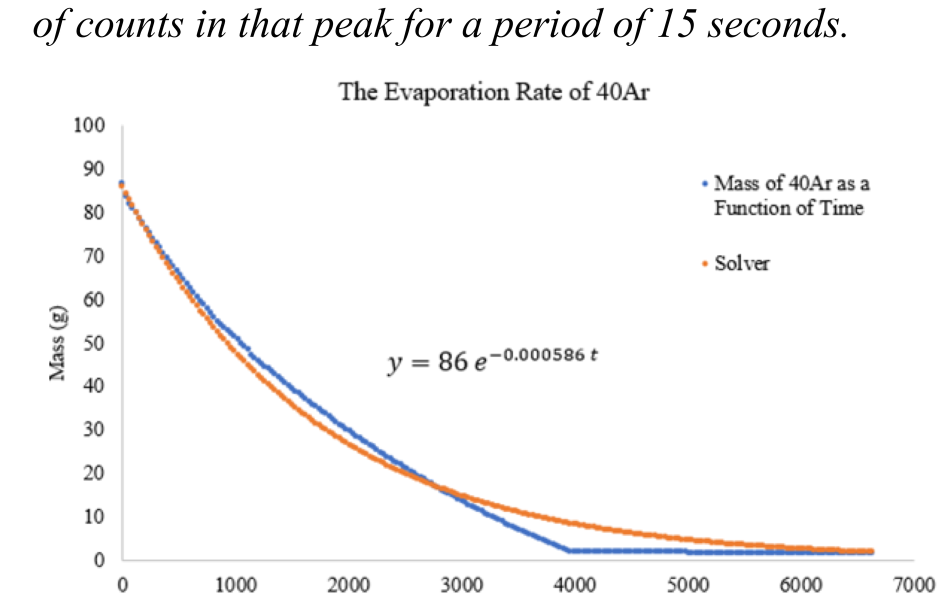
(Right) SUNY Geneseo's Neutron Howitzer contains a stainless steel clad Pu-Be source located in the center of the water tank. Next to the Pu-Be is a vertical PVC re-entrant tube.

The re-entrant tube was constructed close to the 5 Curie Plutonium-Beryllium (Pu-Be) source. For thermal neutrons, the 40Ar(n,gamma)41Ar reaction radiative capture cross section is 0.66 barns. The radioactive 41Ar has a half-life of 109.6 minutes and undergoes beta minus decay into the first excited state of 41K 99% of the time. The first excited state promptly decays to ground state producing a 1293 keV gamma ray.





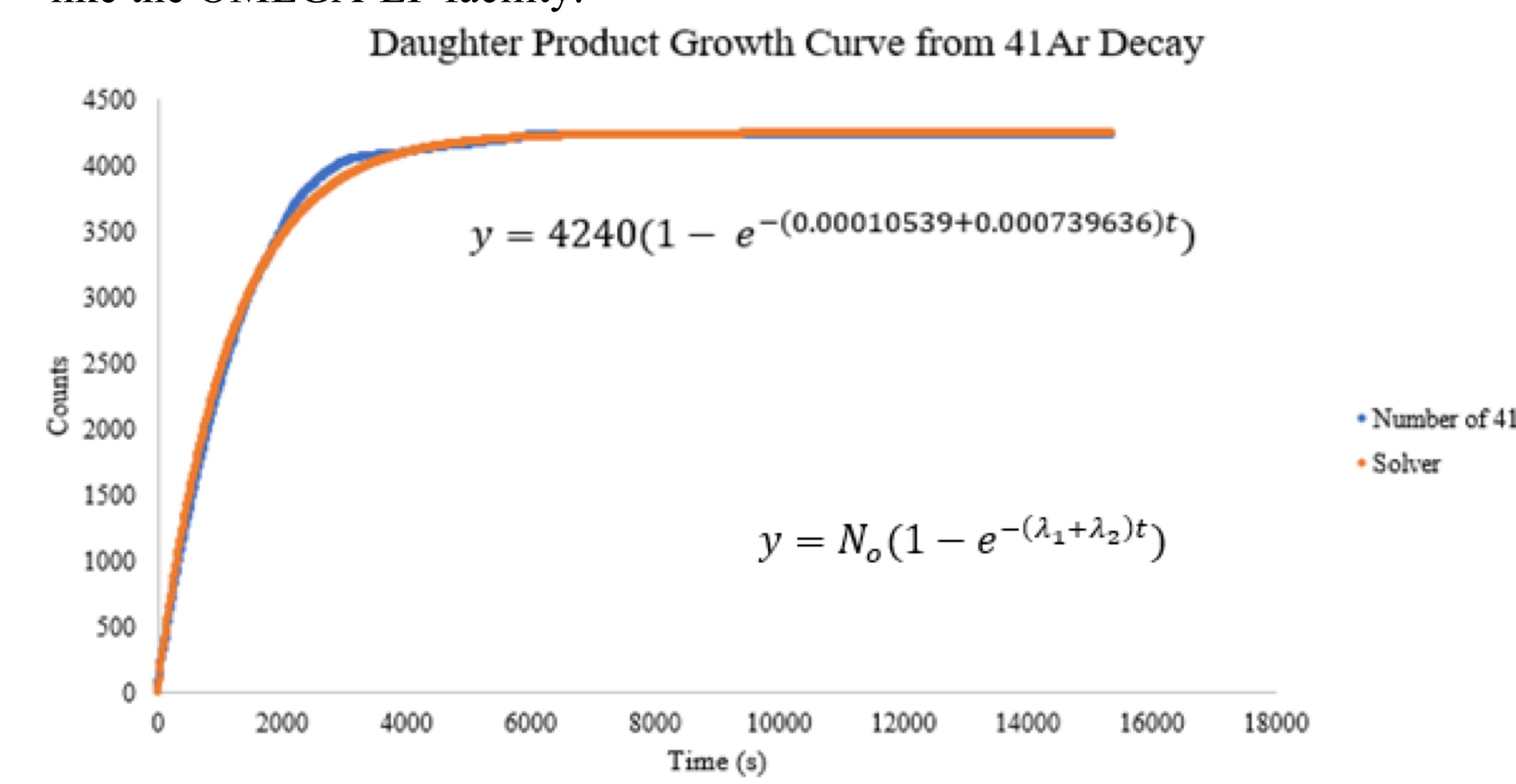
(Left) This graph was created using MPA4, it depicts the number of counts versus channel which were calibrated to the corresponding energy value. The 1,293 keV peak is produced from the decay product 41K when it transitions from the first excited state to the ground state. The 41Ar created is confirmed by the presence of the 1293 keV peak. (Right) This graph isolates the counts in the 1293 keV peak and plots the addition of counts in that peak for a period of 15 seconds.



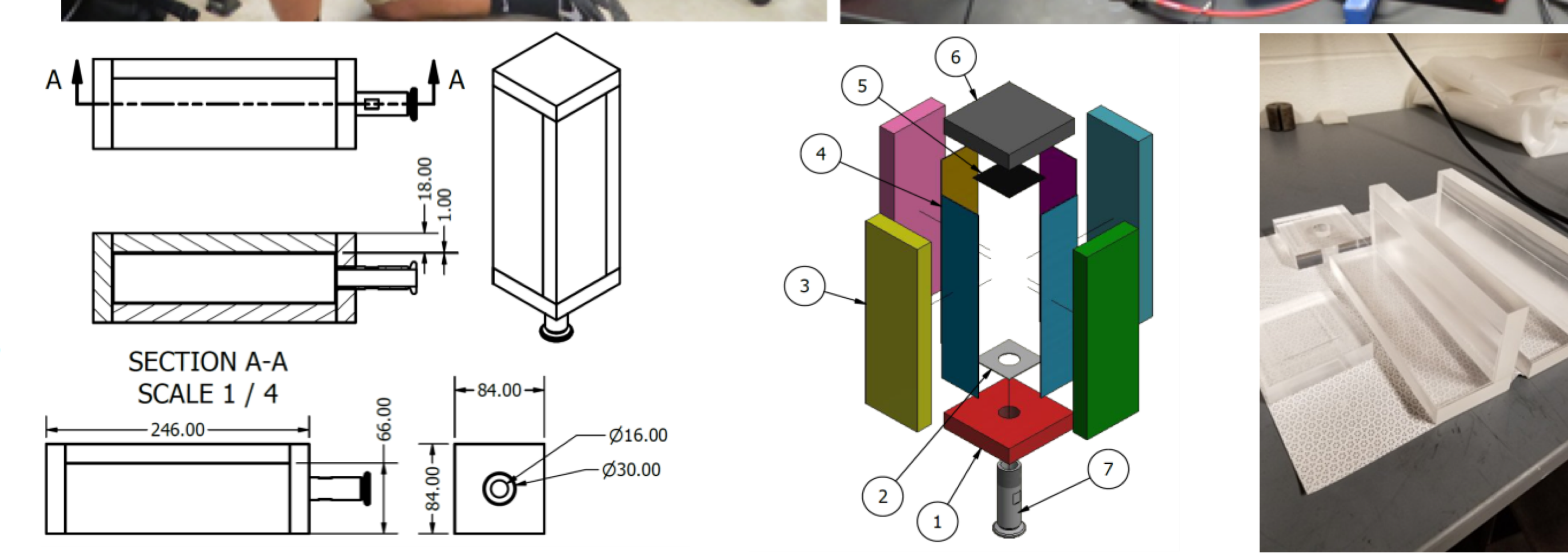
(Left) The graph shows the liquid 40Ar mass loss in the dewar cup measured over a period of two hours. The data collected, in blue, was fit using an exponential decay, in orange.

Results

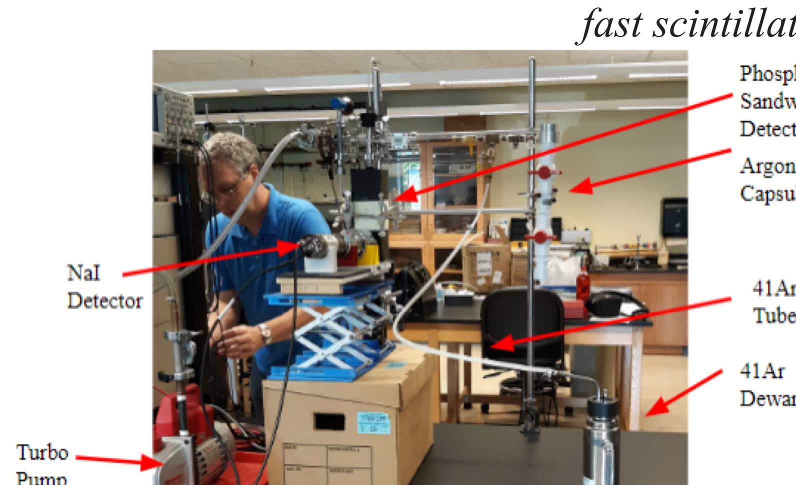
41Ar was made using Geneseo's Neutron Howitzer, it was confirmed using the Gamma-X counting system where the 1293 keV peak was measured in the gamma ray energy spectrum. The result of these measurements showed that tens of thousands of 41Ar nuclei were made per milliliter of liquid 40Ar. The gamma rays and electrons emitted by decay of 41Ar were successfully counted in Gamma-X and RICS. Furthermore, demonstrating that the 41Ar could be used as a useful calibration source for the Houghton RCIS detector at remote locations like the OMEGA-EP facility.



(Above) A growth curve of 41K as a result of the decay of 41Ar and the evaporation of liquid argon



The Houghton Rapit Isotope Counting System. Liquid 41Ar was injected into the system. The RICS successfully counted electrons produced by the decay of 41Ar Hollow phoswich detector. The phoswich detector is a rectangular prism made of plastic scintillator, an outer thick layer made using slow scintillator material, and a thin inner lining made with fast scintillator. All dimensions are in mm.



Funded in part by United States Department of Energy